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Transformations of Hydrocarbons of Ashal'hinskoe Heavy Oil under Catalytic Aquathermolysis Conditions

G. P. Kayukova[a, b, *], L. E. Foss[a, b], D. A. Feoktistov[a, b], A. V. Vakhin[b], N. N. Petrukhina[c], and G. V. Romanov[a]

[a] *Arbuzov Institute of Organic and Physical Chemistry, Kazan Scientific Center, Russian Academy of Sciences, Kazan, Tatarstan, Russia*

[b] *Kazan (Volga Region) Federal University, Kazan, Tatarstan, Russia*

[c] *Topchiev Institute of Petrochemical Synthesis, Russian Academy of Sciences, Moscow, Russia*

**e-mail: kayukova@iopc.ru*

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Abstract—The influence of temperatures of 250, 300, and 350°C on the character of changes in the group and hydrocarbon compositions of heavy oil from the Ashal'chinskoe field in laboratory experiments on the simulation of oil aquathermolysis processes under reservoir conditions has been revealed. The experiments have been carried out in the presence of kaolin as a rock-forming mineral, using oil-soluble iron carboxylate and tetralin as a proton donor. It has been shown that temperature elevation to 300 and 350°C increases the amount of saturated fractions by factors of 1.5 and 1.75, respectively, and decreases the resin content almost by half in comparison with the initial oil. The proportion of *n*-alkanes and light alkylcyclohexane and trimethylalkylbenzene homologues in the saturated fractions increases as a result of cracking reactions involving the preferential degradation of high-molecular-weight resins. A noticeable increase in the amount of newly formed hydrocarbons and asphaltenes at the temperature of 350°C indicates that not only intensive cracking processes, but also condensation processes occur under these conditions. Changes in the quantitative and qualitative composition of the proton donor tetralin by its dehydrogenation to form naphthalene and hydrogenation to yield the *cis*- and *trans*-isomers of decalin have been revealed.

Keywords: heavy oil, composition, temperature, transformations, modeling, aquathermolysis, iron carboxylate, proton donor

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Prospects for industrial development of high-viscosity oil and natural bitumen deposits in Russia, including those in Tatarstan, are due to the growing demand for hydrocarbons, the change in the structure of oil reserves with a predominance of heavy hydrocarbon minerals, and the development of advanced technologies for their extracting and processing [1–4]. In connection with the decline in light oil reserves and a high degree of subsurface prospecting, Tatarstan faces the acute problem of developing alternative sources of hydrocarbon feedstock, which are heavy oils and natural bitumen widespread in Permian-age sediments at depths of up to 500 m from the surface. The pace and amount of development of this type of raw material enriched in heavy hydrocarbons (HC), asphaltene components, organic sulfur compounds, and metal complexes depend on the knowledge of its composition, processes occurring in reservoirs, and improvement in field development methods and technologies [2, 5–8]. The specific features of the composition of heavy oils and natural bitumens make it necessary to launch special studies on the development of new upgrading technologies, including in situ processes or those in ground conditions, the main purpose of which is the conversion of high-molecular-weight components into low-boiling-point hydrocarbons using thermal and steaming technologies [9–11]. Thermal and hydrothermal–catalytic transformations of crude oils and rock organic matter in a steam medium are considered in the literature as one of the methods for modeling hydrocarbon generation processes and the subsequent HC transformation in the sedimentary stratum and in connection with the use of thermal methods for enhanced oil recovery [12, 13]. A number of studies have been published in recent years [13–20] on the mechanism of the influence of rock-forming minerals, nanosized catalysts, and proton donors on changes in the composition and rheological characteristics of heavy oil under the conditions of steam treatment of a petroleum disperse system. Thus, the transformations of high-viscosity oil from the Ashal'chinskoe field (Republic of Tatarstan) during catalytic and noncatalytic aquathermolysis at 300°C in the presence of a rock-forming mineral and a proton